CHAPTER 53

Liquid Scintillation Counting of Radon and its Daughters

Daniel Perlman

Measurements of airborne concentrations of radon and its daughter products are based upon the detection of those ionizations associated with its radioactive decay. One common method of detection employs ion chamber continuous monitors, which are portable, self-contained instruments that can accommodate a scintillation material to measure alpha particles that are emitted in a small collection chamber. Though these measurements can be completed in the order of 10 min, they represent radon concentrations at a specific time and do not necessarily reflect average concentrations measured over longer periods of time.

Etched-track detectors are another means of detecting radon concentrations. These are plastic detectors which are placed within the areas to be measured and then returned to a laboratory. There the tracks, produced in the plastic by the passage by alpha particles, are measured and correlated in ^{222}Rn concentration. These devices, however, are difficult to standardize and calibrate to ambient radon levels.[1]

Charcoal canisters are the principal monitoring devices currently being used. Diffusion canisters containing known amounts of charcoal adsorb ^{222}Rn over a period of approximately one day to one week. These canisters are then sealed and returned to a laboratory where they are counted.[2] Planchette gamma ray counters, typically used to count these detectors, are relatively inefficient, and much of the ^{222}Rn decay signal is not detected.

Liquid scintillation counting has determined the environmental concentration of gaseous radon and its daughters.[3-5] Since this is the only analytical method capable of counting the alpha and beta emissions of radon and its daughter products (Figure 1), it is theoretically the most sensitive procedure available. It was not until an inexpensive and portable means of radon adsorption was developed, however, that liquid scintillation could be considered a practical alternative to those methods previously mentioned.[6] Though it is two or three orders of magnitude more sensitive than planchette counting, liquid

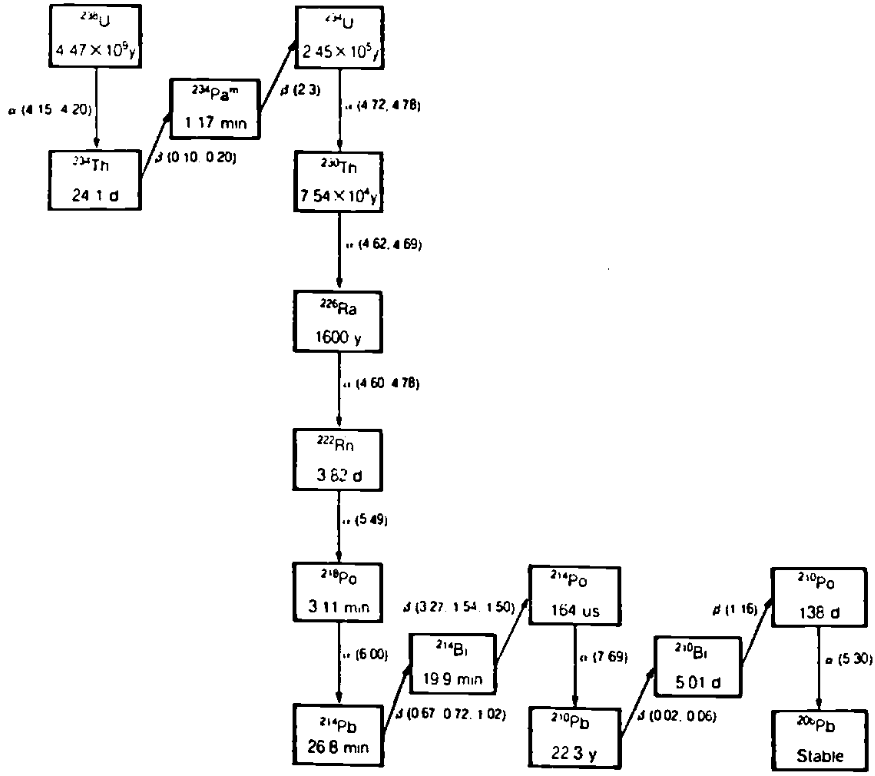

Figure 1. Radon and its daughter products.

scintillation counting inherently involves the generation of liquid scintillation waste.

Optimal extraction of ^{222}Rn and detection of its decay products has been attained in low-molecular-weight alkyl benzenes such as toluene and xylene. Prichard and Marien[6] discovered that radon could be extracted from charcoal by toluene and thereafter counted in conventional toluene based scintillators. Incubation of radon, bearing activated charcoal in xylene or toluene scintillation solutions, resulted in extraction equilibrium and radon daughter ingrowth within 3 to 12 hours. This depended on the size and quantity of charcoal granules and the temperature of extraction. These solvents, however, are associated with relatively high inhalation toxicity and environmental hazard.

Scintillation solvents that have been developed more recently, such as phenylxylylethane and its derivatives, alkyl and dialkylnaphthalene derivatives such as diisopropylnaphthalene, linear alkylbenzenes, substituted biphenyls and other high-molecular-weight aromatic molecules, have been tested for their ability to extract radon from charcoal. Unfortunately, some of these solvents, though biodegradable and much less toxic than toulene or xylene, have only exhibited as little as 20% the radon extraction efficiencies of toluene.

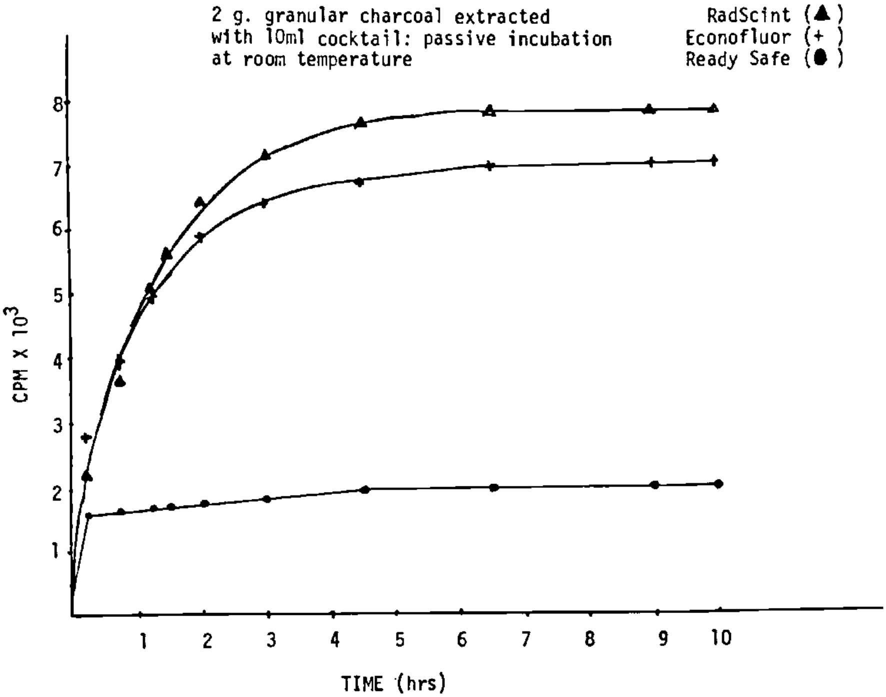

Figure 2. Optimal extraction time of RadScint, Econofluor, and Ready Safe.

A major factor in charcoal detector application is the adsorption of water onto available charcoal binding sites. Increases in relative humidity at the test site will increase moisture pickup by the charcoal, and thus reduce the number of sites available to adsorb radon. Recently it has been reported that in diffusion-limited passive adsorption charcoal detectors desiccant, used in sufficient proportion to charcoal, prevents moisture accumulation in the charcoal.[7]

Experiments were performed to evaluate the efficiency of several commercial scintillation solutions to extract radon from charcoal.

Two grams of dry activated charcoal were placed in conventional 20 mL borosilicate glass scintillation vials. Since varying amounts of water can affect counting and extraction efficiencies, vapor was adsorbed to the dry charcoal at levels of 7.5% (w/w). This represented a relative humidity of approximately 40%, and at 17.4% (w/w), represented a relative humidity of approximately 70%. Vials were exposed in a controlled radon chamber for 96 hr. The vials were removed, filled with 10 mL of liquid scintillation each to be evaluated, allowed to incubate for 8 hr. and then counted. The results of the evaluation are presented in Table 1.

Optimal extraction time was also evaluated for several scintillators (Figure 2). High-molecular-weight solvents with surfactant had a tendency to plateau

Table 1.

	Material	**High Humidity Charcoal ≈ 70% Relative Humidity**		**Low Humidity Charcoal ≈ 40% Relative Humidity**	
		Net CPM	**Relative Efficiency %**	**Net CPM**	**Relative Efficiency %**
CONVENTIONAL SCINTILLATORS	Toluene (5 g/L PPO + 0.05 g/L POPOP)	980	67	1470	100
	Econofluor (DuPont)	968	66	1426	97
	ACS (Amersham)	1011	69	1435	98
	Instafluor (Packard)	953	65	1427	97
	Ready Organic (Beckman)	713	49	1036	70
LOW HAZARD BIODEGRADABLE SCINTILLATORS	Optifluor (Packard)	279	19	294	20
	Ready Safe (Beckman)	204	14	212	14
	Ecolume (ICN)	234	16	270	18
	RadScint (National Diagnostics)	1034	70	1471	100

quickly, but at a relatively low total extraction efficiency (Ready Safe). Conventional solvent based scintillators (Econofluor) generally require 6 to 8 hr to reach equilibrium. Modified high-molecular-weight scintillators, however, equilibrate at approximately the same time as conventional scintillators, 6 to 8 hr but at slightly higher total extraction efficiency.

Clearly, the advantages of low cost, high sensitivity, greater extraction efficiency, and greater reproducibility render liquid scintillation counting the preferred method for radon detection. Problems associated with the disposal of scintillation waste and the occupational exposure hazards of conventional toluene and xylene scintillators can be eliminated by employing the less hazardous, biodegradable solvents that have been modified to improve the extraction efficiencies of radon from charcoal. Scintillation solutions, such as National Diagnostics' RadScint™, have been designed for radon detection with these modified solvents. RadScint enables laboratories to optimize counting and extraction efficiencies of radon samples, while also reducing occupational exposure and hazardous waste generation.

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